COASTAL SYSTEMS

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Contents

Summary

Coasts are functional interfaces where land, sea, and atmosphere meet. The various natural coastal processes appear to be interlinked to a greater or lesser degree and their study requires a systems approach. This is enhanced by increasing human impact.

The boundaries of the coastal system, in the longshore direction as well as cross-shore, are not established. They usually depend on the spatial and temporal scale of the coastal problem to be studied.

The interaction between coastal processes and landforms take place within a morphodynamic system. An external input of energy (e.g. tides, wind) causes water masses to move (e.g. currents, waves) and, if critical boundaries are surpassed, leads to the transport of material (e.g. silt, sand, organic matter). This results in erosive or accretional changes in the morphology and these morphodynamic changes will have a feedback on the system. A negative feedback stabilizes the morphology. A positive feedback causes instability for a relatively short period. In the long run, dynamic systems tend towards stability.

In practice, the application of the coastal systems approach has not been successfully utilized. This is mainly due to the complexity of the coastal system. This complexity increases with the scale. Crucial in this approach is the indication of the smallest functional coastal unit.
In a case study, the establishment of the smallest functional coastal unit is demonstrated for a relatively simple coast. The coastal development at three different scales is explained. It appears that every higher scale level is characterized by a specific steering

mechanism that influences the sedimentation/erosion balance in the underlying coastal units.

1. Introduction

A coast is the transition zone between land and sea. Its geomorphology is mainly determined by fluid dynamic processes, acting on a preexisting, sometimes (partly) relict morphological pattern. The resulting morphodynamics involve complex mutual adjustment of processes and forms. Therefore, the coast is considered a morphodynamic system.

A systems approach is needed to understand their mechanism(s) and to solve coastal problems. The human impact on the coastal environment enforces this approach. This impact is especially important in the case of low-lying coastal areas, which throughout history have been attractive residential areas. These areas have become densely populated and will increasingly do so. About 60% of the world's population lives within 60 km of the sea, and this figure is likely to grow to 75% in the year 2015. Sixteen of the twenty-three mega-cities are situated on the coastal belt. There is increasing competition for diminishing space and resources in the coastal area. Human impacts like coastal defense, harbor and industrial activities, infrastructure, fisheries, agriculture, and the tourist industry place great pressure on coastal environments. It is therefore inevitable that these areas require spatial planning and management in order to steer their development in a sustainable way. The best way to do this is through an integrated systems approach, taking the natural coastal morphodynamic system and the related coastal ecosystems into account, as well as the related socioeconomic and cultural systems. The following account treats the coastal morphodynamic system, with an emphasis on low-lying depositional coasts.

2. Coasts

Coasts are complex areas, characterized by land–sea interaction. On a short timescale, viewed from the sea landward, a coast is affected by hydrodynamic processes produced by tides, currents, waves, and winds that, depending on a number of sea water characteristics (e.g. salinity, temperature) and on the availability of sediment, result in coastal erosion or accretion. The land, due to the geological setting, the lithology and paleo-relief, resists the hydrodynamic processes. Moreover, fluvial, and to a lesser extent eolian, gravitational, and even glacial transported sediments, are supplied to coastal waters from the land side. Animal life and vegetation sometimes contribute substantially to coastal development.

On larger temporal scales, however, other forces are important, as, for example, the changing position of the sea level with regard to the land due to, among other things, changes of the global climate, resulting in an absolute (= eustatic) sea-level rise or sea-level fall. And when a land mass is uplifted or subsiding we deal with a relative sea-level rise or fall.

The cross-shore dimension of a coast is difficult to define precisely, because in landward as well as in seaward direction the border of a coast is variable. It mainly depends on the spatial and temporal scales at which the coast is considered. In a study of actual coastal changes in the Netherlands, for instance, the coast includes usually the zone of active morphodynamics, which for practical reasons extends from approximately 10 m water depth towards the landward boundary of the coastal dunes. A study of Quaternary coastal evolution, however, involves the limits between which coastal processes have been active during the various glacial and interglacial stages of this period. In this case, the whole area between the edge of the continental shelf and the landward limit of the coastal deposits and marine erosion surfaces has to be indicated as the Quaternary coastal zone.

2.1. Spatial and Temporal Scales

Dynamic coastal landforms can develop on various spatial and temporal scales. In the past, attempts to distinguish between coasts at different scale levels have often been based on their geologic and/or geomorphologic development. A well-known distinction, based on (plate) tectonic and morphologic characteristics and determined by dimensions and controls, consists of three consecutive scale levels. A first-order coastal zone, with length, width, and height ranges in the order of 1000 km, 100 km, and 10 km respectively, and controlled by plate tectonics. A second-order coastal zone, with length, width, and height ranges in the order of 100 km, 10 km, and 1 km respectively, and controlled by erosion and sedimentation modifying the first-order features. A shore zone, 1 to 100 km long and 10 m to 1 km wide, controlled by waves and wave-induced currents and sediment size. However, the scale is not supported by the systems paradigm and a temporal entry is missing. A more ambitious attempt deals with a macro-scale, related to variations in the solid boundary state of a coast on a regional scale of hundreds of kilometers, and a meso-scale at the level of individual coastal compartments.

In the last decades of the twentieth century, several authors postulated the relation between the spatial and temporal aspects of developing coastal features. For small-scale features, this can be easily established. The activity of short waves on a sandy seabed results within a few minutes in the genesis of a wave-ripple field (with wave lengths in the order of centimeters). The formation of mega-ripples (with a length scale in the order of meters) on an inter-tidal sandbank in an estuary requires hours to days. Swash bars (which extend over hundreds of meters) need weeks to months for their development.

With an increasing scale level, however, the forms increase not only in volume, but also in complexity. Therefore, it is not yet possible to indicate process descriptions for morphodynamic process–response relations at the larger spatial and temporal scales. Along the sandy coast of the Netherlands, research merely focuses on the mechanics of the cell circulation, which can be considered the most dynamic component of the Dutch coastal system. A process description of the whole coast as a coherent functional unit at different scale levels is a challenge.

2.2. Development and Behavior

When studying coastal development from a scientific point of view, the emphasis is usually on the characteristics of the final geomorphologic stage at the scale level concerned, at the expense of the intermediate characteristics. In an applied sense, however, there is a prominent focus on the intermediate changes of the coastline. Although both approaches overlap, the latter is referred to as coastal behavior to distinguish it from coastal development. Both coastal development and coastal behavior are increasingly affected by human impact.

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Biographical Sketch

Pieter Augustinus (born in Echteld, Netherlands, 1938) studied Physical Geography at Utrecht University. He graduated with his master's degree in 1967. In the same year, he became a research assistant with the Netherlands Foundation for the Advancement of Tropical Research (WOTRO) and continued his studies for a Ph.D. degree. This was focused on the development of the chenier coast of Suriname, a study of the present-day processes of sedimentation and erosion.
In 1969, he was appointed as junior lecturer at the Department of Physical Geography of Utrecht University. In 1974, he became a senior lecturer and remained at this Institute. He continued his research of the tropical muddy coast of Suriname, and obtained his Ph.D. at Utrecht University in 1978.
In the following years, he extended his knowledge to other muddy coasts in the world. In 1984/85 he participated in the Indonesian–Dutch Snellius-II expedition, especially the theme "River Inputs into Ocean Systems." Apart from Indonesia, he participated in research projects on muddy coasts in the Netherlands, France, Suriname, Guyana, China, and recently Vietnam. In 1999, he was appointed Professor in Physical Geography, with an emphasis on coastal morphodynamics.
Throughout these years, he has been a prolific author of scientific articles and has contributed to scientific books on coastal and estuarine geomorphology, especially muddy coastal environments, including salt marshes and mangroves.
He is a member of various scientific organizations and commissions. Between 1996 and 2000, he was Chair of the Commission on Coastal Systems of the International Geographical Union.